| Bonn. zool. Beitr. | Bd. 45 | H. 1 | S. 39—48 | Bonn, April 1994 |
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# Geographic variation in the spring diet of *Falco tinnunculus* L. on the islands of Fuerteventura and El Hierro (Canary Islands)[1])

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Abstract. A study of the diet of the Eurasian kestrel (*Falco tinnunculus*) in semi-desert habitats of Fuerteventura, F, (one of the eastern islands in the Canarian archipelago close to the African coast) is compared with that of the kestrel's diet in humid habitats, which offer great variety in terms of plant life, on El Hierro, H, (the most western of the Canary Islands and the most distant from the African continent). A total of 667 pellets were analyzed from which 9,725 prey specimens were identified (4,820 F; 4,905 H). The kestrel's diet is based on Muridae (32.0 % of biomass F, 33.1 % H), Acrididae (12.7 % F, 14.7 % H) and Lacertidae (12.0 % F, 13.8 % H). Insects were taken most often, particularly Formicidae, Scarabaeidae and Acrididae (F); Scarabaeidae, Acrididae and Tenebrionidae (H). The kestrel's diet was qualitatively very similar on both islands. On El Hierro a certain selective preference for medium to large insects is apparent in contrast to the fact that on Fuerteventura no such preference is shown with insects of a wide range of sizes being caught.

Key words. Aves, Falconidae, *Falco tinnunculus*, diet, El Hierro, Fuerteventura, Canary Islands.

## Introduction

The Eurasian kestrel (*Falco tinnunculus*) is widely distributed in the Canary Islands and occupies all types of habitats, with the exception of laurel forests and mountainous areas at altitudes higher than 2,500 m.

Studies of the diet of this species in the Macaronesian archipelagos (the Azores, the Canary Islands, the Salvages, Madeira and the Cape Verde Islands) are practically non-existent. In the Canary Islands, leaving aside the wide-ranging and painstaking observations of those ornithologists who visited the islands in the past (Godman 1872, Koenig 1890, Lack & Southern 1949, Bannerman 1963, among others), the only noteworthy study is the analysis of 52 stomachs carried out by Polatzek (1908). A more recent study (Carrillo et al. 1986) examined the diet of the Eurasian kestrel on the island of El Hierro during the second part of the winter and the early part of spring.

[1]) Presented at the Congress "Evolution and Conservation in the North Atlantic Islands" (Manchester, England, September 1990).

We report an analysis of the trophic differences in the diet of the Eurasian kestrel on two islands, Fuerteventura and El Hierro, which are heterogeneous in physiography and ecology. Such a study at the southern part of the Western Palaearctic allows for the confirmation of the findings of Valverde (1967), Village (1990) and Aparicio (1990) with regard to latitudinal variation in the capture of prey taxa.

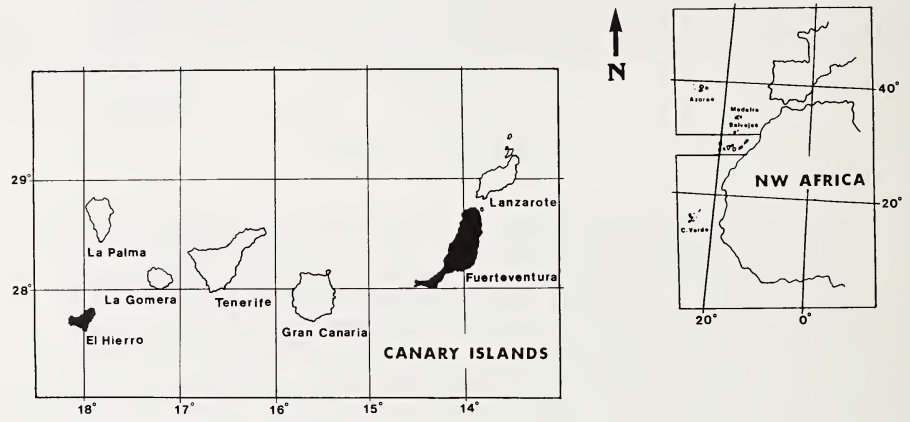


Fig. 1: Geographical location of the Canary Islands. Black areas: the islands covered by the study.

## Study area, materials and methods

The study was conducted in semi-desert areas on Fuerteventura (1662 km²), an island in the eastern region of the Canarian archipelago near the African coast, and in more typically oceanic landscapes on El Hierro (287 km²), which is in the westernmost sector of the Canaries (Fig. 1).

The habitats on Fuerteventura, on which the average annual temperature is 21 ° C and the average annual rainfall under 250 mm, are relatively homogeneous and are characterized by large stony plains, punctuated by gently sloping mountains and gorges. The vegetation on these plains is sparse and scrubby, being composed mainly of *Launaea arborescens*, *Salsola vermiculata*, *Chenoleoides tomentosa* and *Lycium intricatum*.

In marked contrast to Fuerteventura, two of the three habitats under consideration on El Hierro (average annual temperature of 18 ° C and average annual rainfall of 350 mm) exhibit steeper inclines and much denser vegetation with a wider range of species. The study area in the north (in the environs of Frontera) shows a transition from basal floor to forest and is characterized primarily by the presence of small shrubs such as *Hypericum canariense*, *Rumex lunaria*, *Cistus monspeliensis* and *Erica arborea* alongside some crops — mainly vines — and fruit trees. The other area in the south (Los Jables — El Pinar) is in the centre of an ancient pine forest of *Pinus canariensis* which was subject to heavy logging in the past and which now has only scattered pines. Other plants that are characteristic of the landscape are *Euphorbia obtusifolia*, *Rubia fruticosa*, *Echium aculeatum* and *Artemisia thuscula*. The third area (El Tamaduste) is a coastal 'malpais' made up of lava from recent eruptions with sparse, scrubby vegetation such as *Schizogyne sericea* and *Limonium pectinatum*.

A total of 667 complete pellets and a large number of fragments collected from perches during the spring months of the years 1984 to 1988 were analyzed. Those from Fuerteventura (304)

were collected in Vallebrón (16 April 1984), Barranco de Los Molinos (17 February 1985), Cuchillete de Buenavista (4 April 1987), Tiscamanita (6 May 1988) and Aceitunal (12 May 1988). On El Hierro (363), collections were undertaken in Los Jables (16 May 1986), the area around Frontera (27 and 29 May 1986) and El Tamaduste (29 May 1986).

Crichton's (1977) method was used in the analysis of the pellets, with the added element of placing the pellets in a container of water beforehand to aid separation.

Problematic prey was identified by comparison with the collection of the Department of Animal Biology (Zoology) of the University of La Laguna. An average representative weight was used in the calculation of the biomass of known prey species. When biomass was not known the approximate weight of a taxonomically comparable species of a similar size was used (Mañez 1983). Extremely small unidentified invertebrates were not included in the calculations. Vertebrates with a mass >40 g were assigned a biomass of 40.8 g in accordance with the quantity estimated as the maximum daily amount ingested by *F. tinnunculus* (Yalden & Yalden 1985).

The Shannon-Weaver index was used in the calculation of trophic diversity (Margalef 1977). In comparing the diets of the kestrels on both islands, the Sørensen Similarity Coefficient was used (Southwood 1978). Differences in prey mass were calculated by means of the Kolmogorov-Smirnov test (Siegel 1983). Both formulas were applied only to order and/or family levels, depending on the degree of difficulty experienced in the identification of the remains.

The prey size histogram used a logarithmic distribution of the weights of prey in their natural habitats (Schoener 1969) and the exponential function $y = 200 \cdot 3.5^x$ employed by Real (1987), modified in accordance with the size categories occurring in this study.

## Results

### Composition and variation in diet

On El Hierro, 4905 prey items were identified of which 56.1 % were Coleoptera and 31.6 % Orthoptera (Table 1). Scarabaeidae, Acrididae and Tenebrionidae, insects all of which were plentiful on El Hierro during the study period (Nogales 1990), were caught most frequently. However, rodents, despite not being the most frequently taken prey, represented the largest proportion of the consumed biomass at 33.1 %, with *Mus* sp. being the most important (Fig. 2). By biomass, Orthoptera (21.1 %) and Squamata (17.7 %), particularly the lizard *Gallotia galloti*, constituted the other two particularly significant orders.

On Fuerteventura, of the 4820 prey items identified, 40.8 % were Coleoptera, 25.9 % Hymenoptera and 22.9 % Orthoptera. Formicidae, Scarabaeidae, Acrididae and Curculionidae were most commonly consumed. The appearance of 8 Gastropoda, a very unusual prey for the kestrel in the Macaronesian archipelagos and one which has been quoted on one occasion by Ogilvie-Grant on Madeira (in Bannerman & Bannerman 1965), was a curious feature of the study. Mammals provided nearly half the biomass, with Muridae (32.0 %) as the most significant group. Squamata (15.0 %) and Orthoptera (14.8 %) were also important groups in terms of biomass. Birds (Passeriformes) made up nearly twice the biomass on Fuerteventura as on El Hierro.

Vegetable remains and seeds were also present in pellets (12.9 % on El Hierro and 46.09 % on Fuerteventura). Small stones were also found.

### Similarity in diet and size of prey

Trophic diversity was not as great on El Hierro ($H = 1.16$) as on Fuerteventura ($H = 1.46$), although qualitatively the diet was very similar on both islands. At the level

Table 1: Significant items of prey in the diet of *Falco tinnunculus* on Fuerteventura and El Hierro islands. % N: percentage of number of prey items; % B: percentage of biomass; *: < 0.1 %

| Prey | El Hierro | | Fuerteventura | |
|---|---|---|---|---|
| | % N | % B | % N | % B |
| Gastropoda | — | — | 0.1 | * |
| Araneae | 0.2 | * | 0.3 | * |
| Insecta | 95.1 | 40.0 | 91.9 | 25.3 |
| Odonata | 0.2 | 0.1 | 0.8 | 0.2 |
| Lepidoptera | 0.8 | 3.2 | 0.5 | 1.6 |
| Heteroptera | 0.5 | * | 0.9 | 0.1 |
| Orthoptera | 31.6 | 21.1 | 22.9 | 14.8 |
| Acrididae | 24.4 | 14.7 | 20.1 | 12.7 |
| Tettigoniidae | 1.4 | 1.8 | 2.7 | 2.0 |
| Gryllidae | 5.8 | 4.6 | 0.1 | 0.1 |
| Coleoptera | 56.1 | 14.4 | 40.8 | 7.6 |
| Curculionidae | 4.9 | 0.7 | 11.7 | 2.6 |
| Tenebrionidae | 16.0 | 9.1 | 5.4 | 0.7 |
| Scarabaeidae | 32.1 | 3.8 | 21.6 | 2.5 |
| other Coleoptera | 3.1 | 0.8 | 2.1 | 1.8 |
| Hymenoptera | 5.0 | 0.8 | 25.9 | 1.0 |
| Formicidae | 0.4 | * | 21.8 | 0.6 |
| other Hymenoptera | 4.6 | 0.8 | 4.1 | 0.4 |
| Dermaptera | 0.9 | 0.4 | 0.1 | * |
| Invertebrata | 95.3 | 40.0 | 92.3 | 25.3 |
| Reptilia | 2.1 | 17.7 | 4.5 | 15.0 |
| Lacertidae | 1.5 | 13.8 | 4.0 | 12.0 |
| Gekkonidae | 0.1 | 0.5 | 0.4 | 3.0 |
| Scincidae | 0.4 | 2.7 | — | — |
| other Reptilia | 0.1 | 0.7 | — | — |
| Aves (Passeriformes) | 0.4 | 6.8 | 0.7 | 11.2 |
| Mammalia | 2.2 | 35.5 | 2.5 | 48.6 |
| Muridae | 2.1 | 33.1 | 2.0 | 32.0 |
| Sciuridae | — | — | 0.1 | 4.9 |
| Soricidae | — | — | 0.1 | 0.9 |
| Leporidae | 0.1 | 2.4 | 0.3 | 10.8 |
| Vertebrata | 4.7 | 60.0 | 7.7 | 74.7 |
| Total Prey Items | 4 905 | | 4 820 | |

of order or family, 37 prey taxa occurred on Fuerteventura and 27 on El Hierro, with 22 of these being common to both islands. This implies a similarity of 0.69 (69 %).

Trophic spectrum, which was somewhat wider on Fuerteventura, was characterized by a large variety of species (particularly insects) ranging in size from 0.01 g (some Curculionidae, Chrysididae or Chrysomelidae) to the previously mentioned 40.8 g assigned to *Oryctolagus cuniculus*, *Rattus* sp. and *Atlantoxerus getulus*.

On El Hierro, the prey group the kestrel took most often (46 %) was medium to large insects (0.38—1.33 g), such as Tenebrionidae and Acrididae (Fig. 3). In contrast,

on Fuerteventura, size as a factor in selection from among the arthropods was not apparent. On both islands large prey (heavier than 1.33 g) — most often vertebrates — were not frequently caught.

The differences between the two islands in terms of prey size are clearly significant ($D = 0.275$; $p = 0.03$).

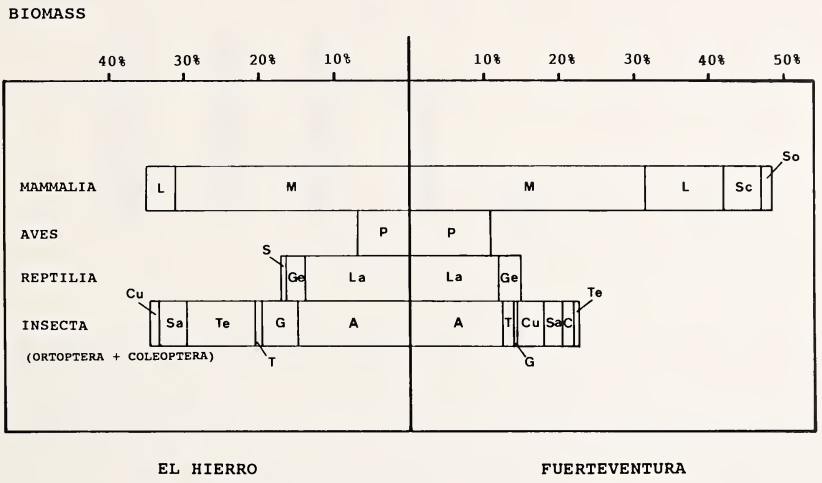


Fig. 2: Proportions of the different items of prey by percent biomass in the spring diet of the kestrel on the islands of El Hierro and Fuerteventura. L: Leporidae, M: Muridae, Sc: Sciuridae, So: Soricidae, P: Passeriformes, S: Scincidae, Ge: Gekkonidae, La: Lacertidae, T: Tettigoniidae, G: Gryllidae, A: Acrididae, Cu: Curculionidae, Sa: Scarabaeidae, Te: Tenebrionidae and C: Carabidae.

## Discussion

As in other zones of the Palaearctic, the diet of the Eurasian kestrel in our study area was made up primarily of small terrestrial prey (Géroudet 1978). In general, the kestrel is a predator with a marked preference for small mammals (Cramp & Simmons 1980) with observable latitudinal differences occurring among the species caught. In the greater part of the north and centre of the Palaearctic the Microtinae form the basis of the diet, while a more pronounced tendency to prey on Murinae occurs in more southern regions (Aparicio 1990). This latitudinal variation was confirmed by studies of the south of the Iberian Peninsula (Valverde 1967, Fernández-Alonso 1985) (Table 2). In the Canary Islands, the Muridae make up the basis of the kestrel's diet, which provides further corroboration for the above finding when the absence of Microtinae is taken into account. Our results contrast with those of Polatzek (1908) in this regard. He found no rodent remains in the 52 kestrel stomachs he examined. A similar contrast occurs with Volsøe's (1951) results, in which rats and mice occurred as only secondary prey. Apart from the Muridae, we found qualitative and quantitative differences among the mammals captured on the two islands. Such differences may be attributable not only to a greater variety of these vertebrates on

Table 2: Diet of the Eurasian kestrel in different regions and seasons of the Western Palaearctic. S: Summer; W: Winter; A: Whole year; AU: Autumm; SP: Spring; U: Unknown; INS: Insecta; ORT: Orthoptera; COL: Coleoptera; INV: Invertebrata; REP: Reptilia; AVE: Aves; MAM: Mammalia; MIC: Microtinae; MUR: Murinae; VER: Vertebrata.

| Country | Latitude | No of items | INS | ORT | COL | INV | REP | AVE | MAM | MIC | MUR | VER | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Norway (U) | 64 | ? | 20.87 | ? | ? | 20.87 | 4.67 | 3.43 | 70.72 | 22.43 | — | 79.13 | Hagen 1952 in Glutz et al. 1971 |
| W Finland (S) | 63 | 2613 | 25.30 | ? | ? | 25.30 | 0.50 | 9.10 | 64.90 | ? | ? | 74.80 | Itämies & Korpimäki 1987 |
| Denmark (?) | 56 | 60 stomach (136 prey) | 22.79 | ? | ? | 23.53 | 2.94 | 5.15 | 68.38 | ? | 64.71 | 76.47 | Ferdinand 1923 in Glutz et al. 1971 |
| Cumbria, England (North) (A) | 54 | 1718 | 86.55 | 11.00 | 30.33 | 86.55 | 0.70 | 0.58 | 12.17 | 7.51 | 0.58 | 13.45 | Yalden & Warburton 1979 |
| N Germany (U) | 54—53 | 516 stomach (803 prey) | 15.57 | 7.22 | 4.11 | 15.69 | 1.25 | 2.49 | 80.57 | ? | ? | 84.31 | Rörig 1905—1907 in Glutz et al. 1971 |
| Sussex, England (A) | 51 | 859 | 41.09 | 4.66 | 31.90 | 41.09 | 2.91 | 16.88 | 39.12 | 23.05 | 4.77 | 58.91 | Shrubb 1982 |
| Normandie, France (W) | 50 | 703 | 39.97 | 22.76 | 17.21 | 39.97 | 0.28 | 0.43 | 59.32 | 50.36 | 0.85 | 60.03 | Thiollay 1963 |
| Paris, France (AU) | 49 | 353 | 17.28 | 1.98 | 7.37 | 17.28 | — | 1.98 | 80.74 | 69.97 | 1.98 | 82.72 | Thiollay 1963 |
| S Germany (U) | 49—48 | 65 stomach (104 prey) | 10.58 | 5.77 | 4.81 | 10.58 | 10.58 | 0.96 | 77.88 | 71.15 | 2.88 | 89.42 | Parrot & Leisewitz, 1905 in Glutz et al. 1971 |
| Vendée, France (S) | 47 | 984 | 20.33 | 1.22 | 19.11 | 20.33 | — | 0.61 | 79.07 | 77.64 | 0.41 | 79.67 | Thiollay 1968 |
| Switzerland (U) | 47—46 | ? | 76.30 | ? | ? | 76.30 | ? | 0.40 | 23.30 | ? | ? | 23.70 | Madon in Géroudet 1978 |
| Camargue, France (S) | 43 | 5869 | 86.52 | 71.46 | 14.79 | 86.52 | 1.06 | 1.36 | 10.72 | 7.09 | | 13.48 | Thiollay 1968 |
| Cuenca C, Spain (A) | 40 | 12623 | 90.66 | 57.31 | 10.31 | 95.81 | 1.52 | 0.46 | 2.23 | 0.93 | 0.32 | 4.21 | Aparicio 1990 |
| Sicily, Italy (U) | 38—37 | 1942 | ? | ? | ? | 74.42 | 3.81 | 0.32 | 21.44 | ? | ? | 25.57 | Massa 1981 |
| P. N. Doñana S, Spain (SP) | 37 | 609 | 44.50 | 12.81 | 29.39 | 46.14 | 23.32 | 8.19 | 22.32 | — | 16.58 | 53.83 | Fernández-Alonso 1985 |
| Fuerteventura, Canary Isl. (SP) | 28 | 4820 | 91.90 | 22.90 | 40.80 | 92.30 | 4.50 | 0.70 | 2.50 | — | 2.00 | 7.70 | Present study |
| El Hierro, Canary Islands (W) | 27 | 3286 | 96.86 | 34.80 | 54.93 | 98.44 | 0.21 | 0.06 | 1.00 | — | 1.00 | 1.27 | Carrillo et al. 1986 |
| El Hierro, Canary Islands (SP) | 27 | 4905 | 95.10 | 31.60 | 56.10 | 95.30 | 2.10 | 0.40 | 2.20 | — | 2.10 | 4.70 | Present study |

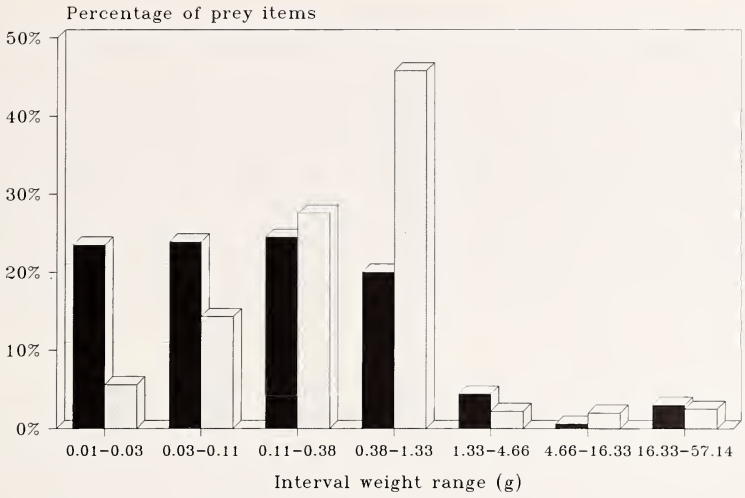


Fig. 3: Variability of size of prey items consumed on El Hierro (grey columns) and Fuerteventura (black columns) according to the frequency of prey caught, related to category of weight assigned. The most important taxa for the different weight range are: 0.01—0.03 (H: Hymenoptera 88.41 %, F: Formicidae 92.05 %); 0.03—0.11 (H: Scarabaeidae 71.61 %, F: Scarabaeidae 65.79 %); 0.11—0.38 (H: Scarabaeidae 79.14 %, F: Curculionidae 38.60 %, Hymenoptera 15.95 %, Acrididae 15.61 %); 0.38—1.33 (H: Acrididae 53.16 %, Tenebrionidae 33.97 %, F: Acrididae 81.78 %, Tettigoniidae 13.66 %); 1.33—4.66 (H: Tettigoniidae 61.82 %, F: Lacertidae 92.45 %); 4.66—16.33 (H: Lacertidae 74.23 %, F: Gekkonidae 75.86 %); 16.33—57.14 (H: Muridae 80.49 %, F: Muridae 64.38 %)

Fuerteventura (Soricidae and Sciuridae are not found on El Hierro), but because the kestrels were at different stages of the reproductive cycle on the two islands.

Although Lacertidae, *Gallotia galloti* in El Hierro and *G. atlantica* on Fuerteventura, are rarely caught, their biomass is substantial for both islands, though not to the extent that it could be considered as a principal food (Koenig 1890, Volsøe 1951 for El Hierro, Bannerman 1963). The proportion of reptiles to the total number of prey was low, as was the case in almost all areas of the Palaearctic Region, with only small differences occurring between the southern and northern parts of the region (Aparicio 1990). Nevertheless, within the vertebrates, the percentages of lizards (52.8 on Fuerteventura, 32.7 on El Hierro) are high, confirming Village's (1990) thesis that an increase occurs at southern latitudes in the Palaearctic.

The frequency of invertebrates in the diet is high on both islands, overtaking the percentages of Coleoptera and Orthoptera, as is generally the case in areas with climates influenced by the Atlantic (Thiollay 1968, Yalden & Warburton 1979, Shrubb 1982, Carillo et al. 1986). The small differences in the kestrel's diet can also be seen as due to the characteristics of the environment. The rugged landscape of El Hierro, its denser vegetation and the existence of large areas of pasture contrast with the characteristics of Fuerteventura where all these factors are less pronounced.

These differences lead to the existence of an entomofauna which varies in terms of heterogeneity (Oromí 1982), which is reflected in the diet of the kestrel. The development of an extremely useful strategy in trophic terms based on the full exploitation of seasonal resources (Davis 1975, Korpimäki 1985). For example kestrel preys upon *Camponotus* spp. (40.3 % of the Formicidae) and on ephemeral *Pachydema* spp. (83.6 % of the Scarabaeidae) both of which swarm or have irruptive populations (Nogales 1990). The ingestion of *Creophillus maxillosus*, a Staphilinidae predator on necrophagous insect larvae (Stanek 1970) suggests that the kestrel makes good use of cadavers to capture the adults and larvae of these arthropods. This phenomenon has been observed on the island of Tenerife (pers. obs.) where fly larvae were found in the stomach of a kestrel that had been hit by a car and had previously been observed feeding on a dead cat.

Both in winter (Carrillo et al. 1986) and in spring, the prey groups the kestrel take most frequently on El Hierro are the Scarabaeidae, Acrididae and Tenebrionidae.

The diet of the kestrel of the Canary Islands has a higher proportion of insects than other more northern populations (e. g. Aparicio 1990, Village 1990), thus confirming the negative correlation between this percentage and latitude (Aparicio 1990). This is logical when the entomological richness of warm regions is taken into account (Zahradnik 1990), a richness which leads the predator to opt for these invertebrates if the time taken in hunting the prey can be reduced. This in turn would lead to a greater use being made of these prey species in these southern latitudes than further north (Veiga 1982), that is, daily biomass is less dependent on chance than on the capture of larger but scarcer prey (Aparicio 1990).

**Acknowledgements**

Vicente Quilis and Mercedes Abdola helped in collecting pellets on Fuerteventura. The identification of some Hymenoptera was carried out by Gloria Ortega. Pedro Oromí made various interesting entomological comments at the same time as identifying some Coleoptera. Jacinto Barquín advised us on the analysis of the results. We wish to express our gratitude to Luis María Carrascal, Pablo Veiga and José Miguel Aparicio for their comments on an earlier draft of the manuscript. Paul Cavanagh and an anonymous referee reviewed the final manuscript and made valuable suggestions. Finally we thank Ana Esther Pérez González for helping with typing the tables.

**Resumen**

Se ha estudiado la alimentación primaveral del cernícalo vulgar en ecosistemas semidesérticos de Fuerteventura, F, (isla oriental del archipiélago próxima a la costa africana) y se ha comparado con la de otros ecosistemas húmedos y de gran riqueza florística de El Hierro, H, (isla más occidental y distante al continente africano). La alimentación ha sido examinada a través del análisis de 667 egagrópilas, identificándose 9.725 presas (4.820 F; 4.905 H). El régimen alimentario está basado en Muridae (32 % de biomasa F, 33.1 % H), Acrididae (12,7 % F, 14,7 % H) y Lacertidae (12 % F, 13,8 % H). Los insectos son las presas más capturadas, en especial Formicidae, Scarabaeidae y Acrididae (F); Scarabaeidae, Acrididae y Tenebrionidae (H). Cualitativamente la dieta es muy semejante en ambas islas (69 %). Se aprecia en El Hierro un cierto criterio selectivo hacia insectos de tamaño medio y grande, no confirmándose este fenómeno entre los diversos tamaños de estos artrópodos capturados en Fuerteventura.

**Zusammenfassung**

Das Nahrungsspektrum von Turmfalken wurde in zwei verschiedenen Regionen der Kanarischen Inseln untersucht; zum einen in halbwüstenartigen Landschaften von Fuerteventura, zum anderen in feuchten und pflanzenreichen Gebieten von El Hierro. Aus 667 Gewöllen wurden 9725 Beuteanteile bestimmt. Die Proben waren annähernd gleich auf beide Inseln verteilt. Die Kanarischen Turmfalken ernährten sich überwiegend von Nagetieren (Muridae, 32.0 % der Biomasse in Fuerteventura, 33.1 % in El Hierro), Heuschrecken (Acrididae, 12.7 und 14.7 %) und Eidechsen (Lacertidae, 12.0 und 13.8 %). Die Insektennahrung setzte sich hauptsächlich aus Formicidae, Scarabaeidae, Tenebrionidae und Acrididae zusammen. Auf beiden Inseln waren die Nahrungsspektren der Falken sehr ähnlich. Bei den Falken von El Hierro deutete sich eine Präferenz für mittlere bis große Insekten an, die bei den Falken von Fuerteventura nicht erkennbar war.

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